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ARMORED MEDICAL RESEARCH LABORATORY
Fort Knox, Kentucky

Project No. T-5
SPMEA 727-2

21 July 1945

1. PROJECT: No. T-5 - Test of Flameproofed Clothing. Second Partial Report.
Subject: Effects of Wearing Flameproofed Clothing in Hot Environments.

a. Authority: Letter, 6th Indorsement, SPMDO 421, ASF, SGO, Washington
25, D. C., 7 December 1944.

b. Purpose: To evaluate the effects of wearing two types of flameproofed clothing in hot environments.

2. DISCUSSION:

In the first partial report on this project, the effects of wearing a type of flameproofed and gasproofed clothing designated therein as "D" were presented. This garment although especially prepared for use in hot climates was found to impose a greater heat load than the standard herringbone twill outfit. The increased heat load was not apparent until the men worked in the more severe environments, simulating those that may be found in buttoned-up tanks (D.B. 120°F., W.B. 88°F.) operating in hot climates. Inasmuch as this added heat load can be critical in determining the duration and effectiveness with which combat tank crews continue operation, flameproofed "D" garments could not be considered entirely satisfactory for issue in very hot climates.

In continuing the evaluation of flameproofed garments for tank crews, a second small batch of flameproofed and gasproofed clothing, "X," was subjected to test. The essential components of this impregnating mixture were identical with those used in the "D" impregnation. It is to be noted that the constituents of the two impregnating agents are the same, with the exception that the "X" garments contained twice as much aluminum stearate in the garment. The final pickup of impregnate of both was practically equal.

3. CONCLUSIONS:

In hot environments (D.B. 120°F., W.B. 88°F.):

a. The heat load imposed by a single layer of either flameproofed "X" twill or herringbone twill is similar.

b. The heat load imposed by flameproofed "D" clothing is definitely greater than that imposed by either the flameproofed "X" or herringbone twill outfits.

* Test of Flameproofed Clothing, Project No. T-5, AMFL, 17 July 1945.

** D.B. = Dry Bulb Temperature
W.B. = Wet Bulb Temperature

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c. Throughout the test, the physical characteristics of flameproofed "X" clothing closely resembled those of herringbone twill in sharp contrast to the appearance of flameproofed "D" garments.

d. Neither flameproofed clothing "X" nor "D" produced acute toxic changes of a local or systemic nature in the wearers.

4. RECOMMENDATIONS:

a. That flameproofed "X" clothing be considered unsatisfactory for issue to troops because the flame resistance of flameproofed "X" garments was inferior to that of flameproofed "D" garments, both before and after wear.*

b. That this report be considered in conjunction with the other partial reports from this laboratory.

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4 Incls.

- #1 - Appendix
- #2 - Tables I thru V
- #3 - Charts 1 and 2
- #4 - Photograph

* N.R.C. Project C.M.C. No. 27, Sub-Project 27-A5-X-2, Subj: The Flameproofing of Army Clothing, 30 April 1945.

C O N F I D E N T I A L

APPENDIX

1. Subjects, Experimental Conditions and Procedures

This work was conducted as a part of the studies presented in the first partial report.* The subjects, experimental conditions and procedures were identical with those described in the first partial report. However, the present study was carried out in only one environment; viz, D.B. 120°F., W.B. 88°F., R.H. 28%. The men wore the following types and assemblies of clothing which were prepared by Chemical Warfare Service.

a. Herringbone Twill (HBT), single layer - half wool socks, service shoes, cotton shorts, two piece fatigue uniform of herringbone twill.

b. Flameproofed assembly "X," single layer - half wool socks, service shoes, cotton shorts, flameproofed two piece fatigue uniform herringbone twill (Formula X).

c. Flameproofed assembly "D," single layer - half wool socks, service shoes, cotton shorts, flameproofed two piece fatigue uniform of herringbone twill (Formula D).

The flameproofed and gasproofed clothing was of two kinds, "X" and "D." They were prepared by impregnation with the same chemicals. However, the "X" formula contained twice as much aluminum stearate as the "D." Flameproofed "X" clothing consisted of HBT jacket or trousers which had been impregnated with the following formula: chlorinated paraffin/CC-2/zinc oxide/aluminum stearate/acetylene tetrachloride/139/139/139/34.8/1390. The pickup amounted to 40%. The garments were not laundered.

Flameproofed "D" clothing was impregnated with: chlorinated paraffin/CC-2/zinc oxide/aluminum stearate/acetylene tetrachloride/139/139/139/17/1623. The initial pickup was 47% which was considered excessive and was reduced by one laundering to 38%. The pickup of impregnate in both batches at the start of the test was, therefore, practically equal.


2. Results

In the first partial report of this project, it was shown that no differences in response to wearing either herringbone twill or flameproofed "D" clothing could be demonstrated in moderately warm environments; e.g., D.B. 100°F., W.B. 80°F. Differences appeared only in severe environments. Accordingly, to evaluate the relative merits of the two flameproof garments, tests were run at D.B. 120°F., W.B. 88°F. which also simulates conditions that may be found in tanks in hot climates.

a. Physiologic Effects of Flameproofed "X" Garments and Herringbone Twill.
A study of the heat loads imposed on men by both flameproofed "X" and herringbone twill outfits was carried out during the period of acclimatization to a hot

* Test of Flameproofed Clothing, Proj. No. T-5, 1st Partial Report, AMRL, 17 July 45.

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environment; D.B. 120°F., W.B. 88°F. In Chart 1 and Table I are shown the responses of the men clothed in the two types of garments on the first, fifth and eighth day of exposure to the heat. On the first day, the men were required to walk only one (1) hour; on the fifth day, two hours and on the eighth day, four hours. Originally the two groups were each composed of 5 men. On the fifth day, McK and Nau were both ill so that their response may not be representative. Nau is not shown in Chart 1 and Table I on the 8th day since he became ill and was dropped from the problem.

The men in flameproofed "X" garments experienced a heat load similar to that found in the men in herringbone twill. The average rectal temperature, pulse, sweat loss and skin temperature showed no significant differences. The men, however, felt that the flameproofed "X" garments were hot and uncomfortable.

The data in Table I also illustrate the typical pattern of acclimatization. Apparently the wearing of flameproofed "X" clothing did not alter the course of normal acclimatization.

b. Physiologic Effects of Flameproofed "D" Garments and Herringbone Twill.

It was shown in the first partial report that at D.B. 120°F., W.B. 88°F. the flameproofed "D" garments imposed a greater heat load on men than did herringbone twill.

c. Direct Comparison of Physiologic Effects of Flameproofed "X" and Flameproofed "D" Clothing. On two consecutive days at D.B. 120°F., W.B. 88°F., ten acclimatized men (Chart 2, Table II) alternately wore flameproofed "X" and flameproofed "D" assemblies. The flameproofed "X" garments had been worn 30 hours at 120/88 while the flameproofed "D" twill had been worn 4 hours previously. Significantly higher rectal temperatures were found in the same men when wearing flameproofed "D" clothing. The men reported that the flameproofed "D" garment was much more uncomfortable to wear stating that it felt hotter than the "X."

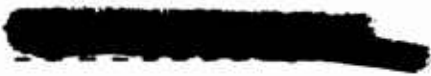
It was concluded that on comfort and heat load criteria alone, flameproofed "X" clothing is superior to flameproofed "D" clothing for use in hot climates.

3. Physical Characteristics of the Clothing

a. Gross Characteristics. Type "D" flameproofed twill garments have been described previously. Their stiffness, coarseness and general uncomfortableness were not appreciably altered with wear. This flameproofed clothing was resistant to wetting and while some improvement was noted, it never attained the wetting qualities exhibited by untreated herringbone twill.

Type "X" flameproofed twill garments when received for test were heavy and had a waxy appearance but were not particularly stiff or coarse. After the initial wearing, they became as pliable as herringbone twill. The greater weight of the "X" garments persisted unchanged throughout the study.

Flameproofed clothing "X" also differed from "D" in that it did not show particular resistance to wetting (Photograph 1). In general, it appeared to



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be wetted as readily as herringbone twill. Type "X" garments differed somewhat from herringbone twill in that, while it was as completely wetted, it never absorbed the same quantities of moisture. This was undoubtedly related to the presence of the flame treatment materials which took up some of the space available for absorption.

All subjects preferred type "X" flameproofed garments to type "D." The primary reason was related to the greater ease of wetting type "X" garments.

b. Absorption of Water. Studies on the sweat uptake during the walking periods were performed. The clothing was dried for at least fourteen (14) hours before being taken into the hot room prior to the day's work. The individual items of clothing were weighed to within five (5) grams immediately before and after the walking period. Table III indicates the close similarity between the moisture uptake of untreated herringbone twill and type "X" flameproofed twill. In a previous report, it was shown that type "D" flameproofed twill exhibited relatively poor water uptakes even after considerable wear in comparison to untreated herringbone twill.

This suggested difference between the two kinds of flameproofed garments is borne out by the data presented in Table IV. The greater ability of type "X" to absorb moisture is not as evident during the initial wear because of the almost three-fold greater period of wear for type "D.". The superiority of "X" is quite marked by the tenth wearing when these garments have absorbed nearly twice as much moisture despite a smaller amount of available water. This increased water absorbing capacity of "X" clothing was not due to the leaching out of the flameproofing compound for the weight of these flameproofed garments did not increase with repeated wear (Table V).

4. Toxic Effects

No toxic effects attributable to either type of impregnation were encountered. Neither generalized systemic effects nor local cutaneous toxic reactions resulting from direct contact were seen. Cutaneous lesions attributable to friction of the clothing were encountered and have been discussed in a previous report.

5. Flame Resistance of the Clothing

A report on flame-resisting properties of the articles of clothing used in this test has been submitted by another agency.* Type "X" clothing was not as resistant as type "D." As a result of wear in environmental conditions where sweat output is nearly maximal, type "D" lost some of its flameproof qualities while type "X" lost nearly all. In fact, worn type "X" flameproofed clothing burned nearly as readily as untreated herringbone twill. This was difficult to understand as there was no change in the weight of the "X" garment which indicated that the impregnate was still present.

This failure to retain adequate flameproofness eliminates "X" clothing from consideration for use.

* N.R.C. Project Q.M.C. No. 27, Sub-Project 27-A5-X-2, Subj: The Flameproofing of Army Clothing, 30 April 1945.

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TABLE I - THE PHYSIOLOGIC RESPONSES OF WORKING MEN WEARING
FLAMEPROOFED "X" TAIL AND HERRINGBONE TAIL DURING ACCLIMATIZATION
D.B. 120°F., W.B. 88°F.

DAY	CLOTHING	NAME	HOURS WALKED	RECTAL TEMPERATURE °F					PULSE RATE/MIN.					SKIN TEMP. (AVE. WT.G.)		WEIGHT LOSS Gm/Hr.
				Hours					Hours					Init.	Final	
				0	1	2	3	4	0	1	2	3	4			
1 st	H.B.T.	Wei	1.0	99.5	104.0				117	201		98.5	101.0	708		
		Ljn	1.0	99.5	102.4				114	144		96.9	100.0	1223		
		Ste	1.0	99.2	103.5				138	168		97.3	100.9	1069		
		Nau	0.8	99.0	102.1*				114	176*		-	-	1058		
		Wlc	1.0	99.2	102.5				132	150		99.7	100.5	1046		
	F.P."X"	AVG		99.3	103.1				123	166		98.1	100.6	1021		
		Kne	1.0	98.8	103.1				90	171		98.2	100.9	862		
		Dlm	1.0	99.5	-				105	177		98.2	100.6	894		
		Szu	1.0	99.4	102.5				117	174		98.5	99.1	646		
		Kac	1.0	99.0	102.5				114	177		97.3	100.4	846		
5 th	H.B.T.	Wei	2.0	99.1	102.7	103.8			120	135	150	99.0	100.5	952		
		Ljn	2.0	99.2	101.6	102.1			96	135	135	97.3	97.8	1788		
		Ste	2.0	98.8	101.6	102.5			126	150	136	97.4	99.7	1289		
		Nau	1.5	98.6	102.0	102.3*			96	120	168*	-	-	1124		
		Wlc	2.0	99.1	101.1	101.4			135	153	132	97.5	98.5	1361		
	F.P."X"	AVG		99.0	101.8	102.4			115	139	139	97.8	99.1	1303		
		Kne	2.0	98.5	101.2	102.4			90	144	132	97.3	99.1	1300		
		Dlm	2.0	98.8	102.2	102.5			96	156	144	97.1	98.9	1251		
		Szu	2.0	98.9	101.5	101.8			120	156	147	97.7	99.4	1276		
		Kac	2.0	98.5	100.9	101.5			102	138	132	98.1	98.8	1134		
8 th	H.B.T.	Wei	4.0	98.6	101.4	102.4	103.3	103.6	108	138	120	144	135	916		
		Ljn	4.0	99.3	101.3	101.8	101.8	102.2	99	123	111	126	114	1670		
		Ste	4.0	98.3	100.8	101.5	102.2	102.6	96	132	126	123	129	1306		
		Wlc	4.0	98.8	100.6	101.2	101.4	101.7	114	138	126	129	138	1389		
		AVG		98.8	101.0	101.7	102.2	102.5	104	133	121	130	129	1320		
	F.P."X"	Kne	4.0	98.7	101.0	100.7	101.0	101.2	99	114	120	129	120	1414		
		Dlm	4.0	98.2	100.6	101.5	101.5	101.4	96	132	129	117	138	1199		
		Szu	4.0	98.4	100.5	100.8	101.2	101.3	108	132	123	120	117	1306		
		Kac	4.0	98.4	100.6	101.2	101.8	102.3	111	144	141	129	150	1126		
		Mck	4.0	98.5	100.8	102.0	102.6	103.6	111	147	153	138	156	1264		
AVG		98.4	100.7	101.2	101.6	102.0	105	133	133	127	136	1262				

*Data taken at time of cessation of walking - not used in averages for that hour.
† The men were required to walk only 1 hour on the 1st day and 2 hours on the 5th day in the heat.

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TABLE II
The Physiologic Responses of Working Men wearing
Flameproof (X) Twill and Flameproof (D) Twill

D.B. 120°F. - W.B. 88°F.

CLOTHING	GROUP	NAME	RECTAL TEMPERATURE °F					PULSE RATE/MIN.					SKIN TEMP. (Avg. Mtg.) °F	WEIGHT LOSS (Sweat) Gm/Hr.	
			Hours					Hours							
			0	1	2	3	4	0	1	2	3	4			Init.
FLAMEPROOF (X)	A & B	Kne	98.5	100.1	100.3	100.1	100.4	99	117	102	120	120	97.0	97.0	1718
		Szu	99.0	100.0	100.3	100.0	100.3	102	135	120	123	135	97.6	98.1	1395
		Dim	98.6	101.1	101.2	100.7	100.3	102	147	126	120	120	97.0	97.0	1394
		Mar	98.2	100.4	101.3	100.2	100.5	114	150	132	132	129	97.5	97.9	1571
		Kac	99.0	100.7	100.4	100.2	100.4	114	147	135	144	147	96.9	98.1	1297
		Lin	98.6	100.6	101.0	100.5	100.5	81	114	117	111	114	97.1	96.7	1884
		Sec	98.8	101.0	101.0	100.7	100.6	117	141	135	129	123	97.3	96.3	2038
		Mic	98.9	100.0	100.3	99.9	99.8	108	123	120	123	114	97.4	96.9	1690
		Low	98.6	101.0	101.7	101.5	101.3	108	135	135	117	129	97.7	98.1	1475
		Hll	98.3	100.0	100.7	100.6	100.8	99	117	114	132	117	97.0	98.1	1327
AVG.	98.6	100.5	100.8	100.4	100.5	104	133	124	125	125	97.2	97.4	1579		
FLAMEPROOF (D)	A & B	Kne	98.8	100.8	101.5	101.6	101.5	102	123	117	108	117	97.2	99.1	1755
		Szu	98.4	100.6	101.4	101.4	101.4	99	129	135	138	129	97.7	98.7	1482
		Dim	98.4	101.3	101.6	101.3	101.0	81	135	132	129	132	97.2	97.8	1701
		Mar	98.6	101.2	101.5	101.3	101.0	111	153	153	153	144	97.8	98.0	1752
		Kac	98.7	101.1	102.1	101.1	100.8	108	153	144	129	150	96.9	97.9	1527
		Lin	98.8	101.7	102.3	102.4	102.5	96	120	117	126	123	97.7	99.7	2040
		Sec	99.1	101.7	102.2	101.9	102.0	96	135	132	126	135	97.8	98.3	2098
		Mic	99.0	100.9	101.0	101.2	101.4	114	159	138	132	126	97.5	98.9	1791
		Low	99.0	101.6	101.5	101.5	102.2	99	141	132	123	129	97.4	99.6	1629
		Hll	98.5	100.7	101.0	100.7	101.2	108	120	120	126	123	97.3	99.0	1298
AVG.	98.7	101.2	101.6	101.4	101.5	101	137	132	129	131	97.4	98.7	1707		

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TABLE III

The Sweat Absorbed by Flameproofed and Herringbone
Twill Two-piece Fatigue Uniforms during Work

D.B. 120°F - W.B. 88°F

(Data are the Average for the Clothing of Five Men)

	T Y P E O F G A R M E N T			
	First Wearing		Sixth Wearing	
	Herringbone Twill	Flameproof Twill "X"	Herringbone Twill	Flameproof Twill "X"
Hours of Wear	1.3	1.3	4.0	4.0
Water Absorbed (Grams)				
Jacket	191	183	408	364
Trousers	40	52	261	207
Assembly	231	235	669	571
Total Sweat of Subject (Grams)	1359	1096	5156	4785

~~C O N F I D E N T I A L~~
TABLE III

C O N F I D E N T I A L

TABLE IV

The Sweat Absorption by Two Types of Two-piece Flameproofed
Herringbone Twill Uniforms as Influenced by
Repeated Wear

D.B. 120° F - W.B. 88° F

(Data are the Average for the Clothing of Five Men)

	T Y P E O F G A R M E N T			
	First Wearing		Tenth Wearing	
	Flameproof Twill "X"	Flameproof Twill "D"	Flameproof Twill "X"	Flameproof Twill "D"
Hours of Wear	1.3	3.6	4.2	3.5
Water Absorbed (Grams)				
Jacket	183	143	543	306
Trousers	52	141	483	305
Assembly	235	284	1026	611
Total Sweat of Subjects (Grams)	1096	5722	6710	8181

C O N F I D E N T I A L

TABLE IV

C O N F I D E N T I A L

TABLE V

Weight of Flameproofed Clothing Before and After the
Last Wearing

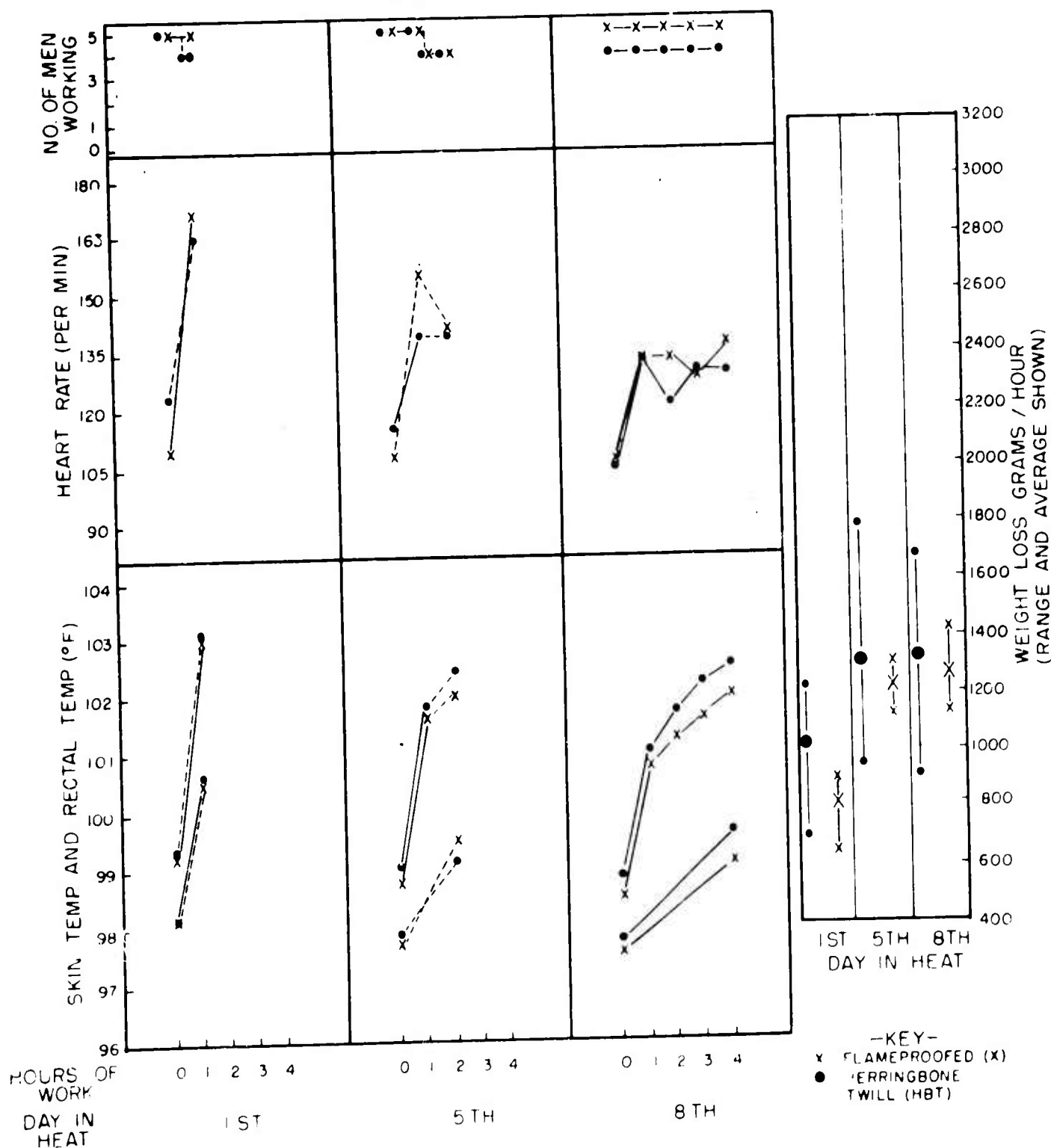
(Data are the Average of Five Uniforms of
Type "X" and Ten Uniforms of Type "D")

	Jacket	Trousers
<u>Flameproofed Twill "X"</u>		
Initial Weight (Gm)	960	836
Final Weight (Gm)	948	839
<u>Flameproofed Twill "D"</u>		
Initial Weight (Gm)	1098	960
Final Weight (Gm)	1106	980

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C O N F I D E N T I A L

CHART I
AVERAGE PHYSIOLOGIC RESPONSE OF WORKING MEN WEARING
FLAMEPROOFED (X) TWILL AND HERRINGBONE TWILL
D.B. 120° F - W.B. 88°F



Incl. #3

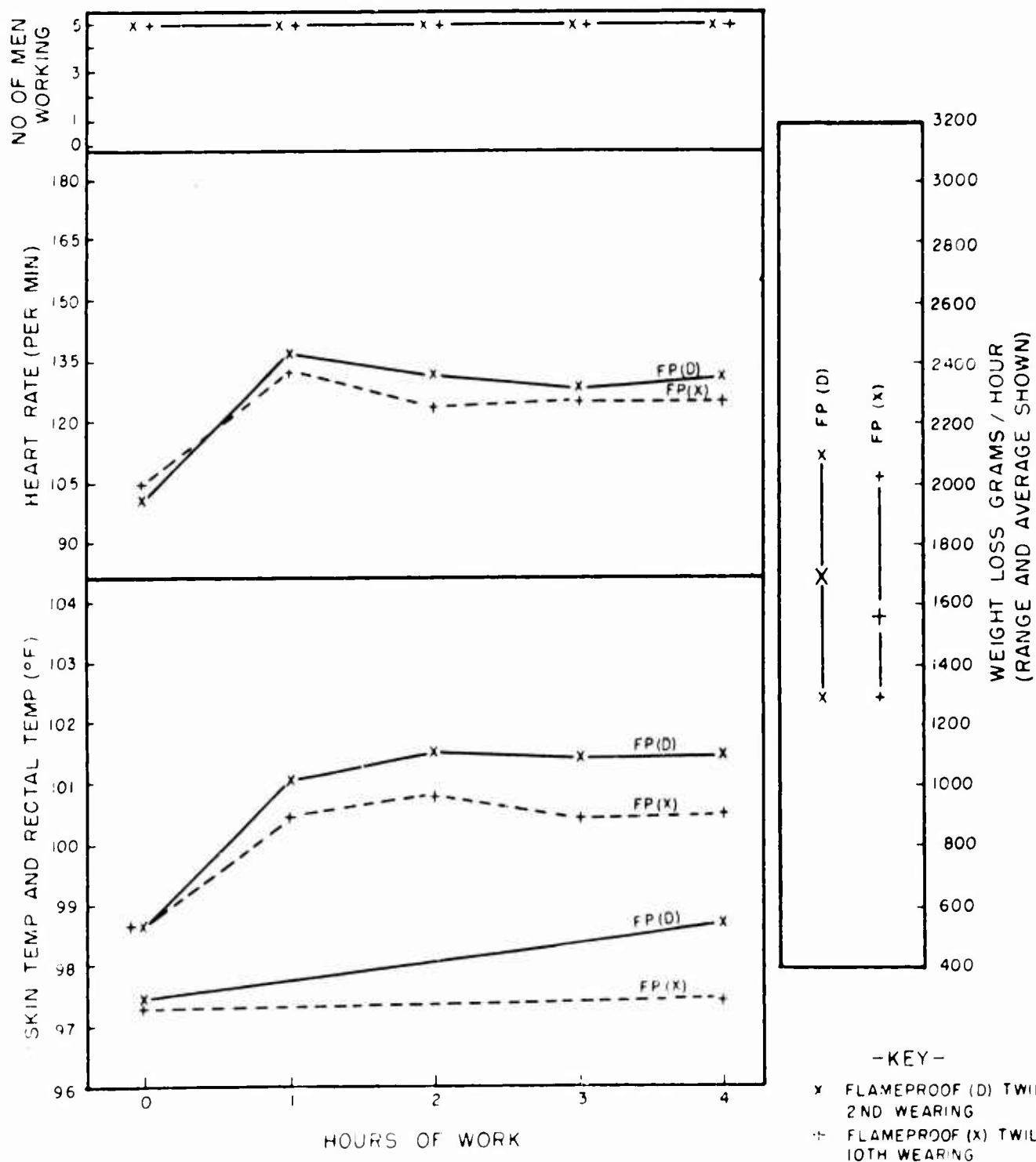
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CHART 2

AVERAGE PHYSIOLOGIC RESPONSE OF WORKING MEN WEARING
FLAMEPROOFED (X) TWILL AND FLAMEPROOFED (D) TWILL

D.B. 120°F - W.B. 88°F



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FP (D)	FP (X)
Appearance of flameproof clothing (X) after ten wearings and flameproofed trill (D) after second wearing.	
ARMORED MEDICAL RESEARCH LABORATORY	
Project No. T-5	FORT KNOX, KY.
	Photograph #1

Incl. #4